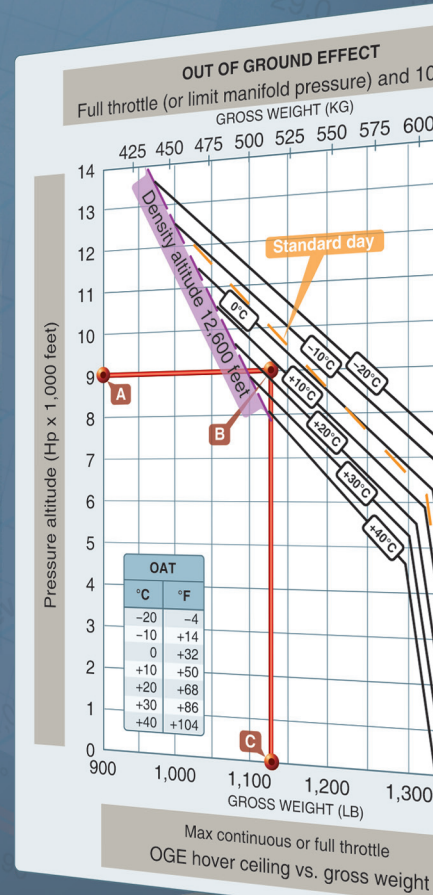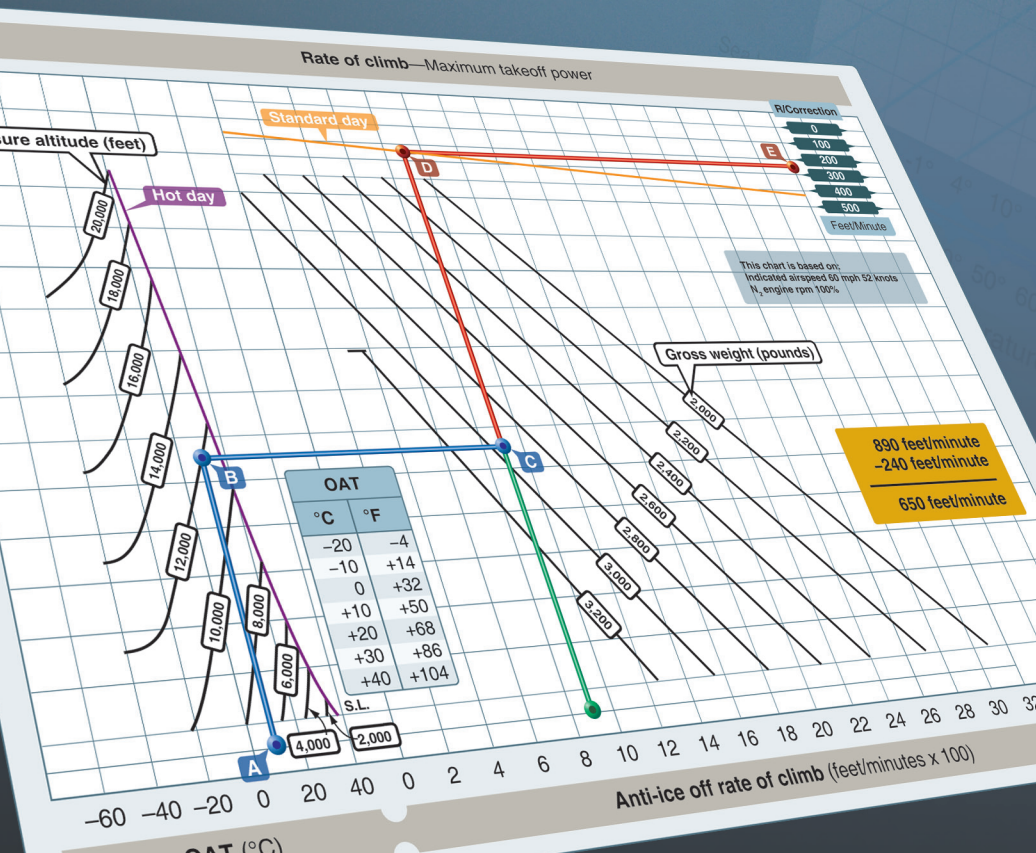## Chapter 7
Helicopter Performance

Introduction

A pilot's ability to predict the performance of a helicopter is extremely important. It helps to determine how much weight the helicopter can carry before takeoff, if the helicopter can safely hover at a specific altitude and temperature, the distance required to climb above obstacles, and what the maximum climb rate will be.

OUT OF GROUND EFFECT
Full throttle (or limit manifold pressure) and 10...
GROSS WEIGHT (KG)

OAT	
°C	°F
−20	−4
−10	+14
0	+32
+10	+50
+20	+68
+30	+86
+40	+104

GROSS WEIGHT (LB)

Max continuous or full throttle
OGE hover ceiling vs. gross weight

Rate of climb—Maximum takeoff power

R/Correction
0
100
200
300
400
500
Feet/Minute

This chart is based on:
Indicated airspeed 60 mph 52 knots
N₂ engine rpm 100%

Gross weight (pounds)
2,000
2,200
2,400
2,600
2,800
3,000
3,200

890 feet/minute
−240 feet/minute

650 feet/minute

OAT	
°C	°F
−20	−4
−10	+14
0	+32
+10	+50
+20	+68
+30	+86
+40	+104

Anti-ice off rate of climb (feet/minutes x 100)

TAKE-OFF DISTANCE
(Feet to Clear 50 Feet Obstacle)

Gross Weight Pounds	Pressure Altitude Feet	At −13°F −25°C	At 23°F −5°C	At 59°F 15°C	At 95°F 35°C
2,150	SL	373	401	430	458
	2,000	400	434	461	491
	4,000	428	462	494	527
	6,000	461	510	585	677
	8,000	567	674	779	896
2,500	SL	531	569	613	652
	2,000	568	614	660	701
	4,000	611	660	709	759
	6,000	654	727	848	986
	8,000	811	975	1,144	1,355
2,850	SL	743	806	864	929
	2,000	770	876	929	1,011
	4,000	861	940	1,017	1,102
	6,000	939	1,064	1,255	1,538
	8,000	1,201	1,527	—	—

$$\frac{1{,}102+1{,}538}{4} \times 2 = 1{,}320$$

Factors Affecting Performance

A helicopter's performance is dependent on the power output of the engine and the lift produced by the rotors, whether it is the main rotor(s) or tail rotor. Any factor that affects engine and rotor efficiency affects performance. The three major factors that affect performance are density altitude, weight, and wind. The Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25, discusses these factors in great detail.

Moisture (Humidity)

Humidity alone is usually not considered an important factor in calculating density altitude and helicopter performance; however, it does contribute. There are no rules of thumb used to compute the effects of humidity on density altitude but some manufacturers include charts with 80 percent relative humidity columns as additional information. There appears to be an approximately 3–4 percent reduction in performance compared to dry air at the same altitude and temperature, so expect a decrease in hovering and takeoff performance in high humidity conditions. Although 3–4 percent seems insignificant, it can be the cause of a mishap when already operating at the limits of the helicopter.

Weight

Most performance charts include weight as one of the variables. By reducing the weight of the helicopter, a pilot may be able to take off or land safely at a location that otherwise would be impossible. However, if ever in doubt about whether a takeoff or landing can be performed safely, delay your takeoff until more favorable density altitude conditions exist. If airborne, try to land at a location that has more favorable conditions, or one where a landing can be made that does not require a hover.

In addition, at higher gross weights, the increased power required to hover produces more torque, which means more antitorque thrust is required. In some helicopters during high altitude operations, the maximum antitorque produced by the tail rotor during a hover may not be sufficient to overcome torque even if the gross weight is within limits.

Winds

Wind direction and velocity also affect hovering, takeoff, and climb performance. Translational lift occurs any time there is relative airflow over the rotor disk. This occurs whether the relative airflow is caused by helicopter movement or by the wind. As wind speed increases, translational lift increases, resulting in less power required to hover.

The wind direction is also an important consideration. Headwinds are the most desirable as they contribute to the greatest increase in performance. Strong crosswinds and tailwinds may require the use of more tail rotor thrust to maintain directional control. This increased tail rotor thrust absorbs power from the engine, which means there is less power available to the main rotor for the production of lift. Some helicopters even have a critical wind azimuth or maximum safe relative wind chart. Operating the helicopter beyond these limits could cause loss of tail rotor effectiveness.

Takeoff and climb performance is greatly affected by wind. When taking off into a headwind, effective translational lift is achieved earlier, resulting in more lift and a steeper climb angle. When taking off with a tailwind, more distance is required to accelerate through translation lift.

Performance Charts

In developing performance charts, aircraft manufacturers make certain assumptions about the condition of the helicopter and the ability of the pilot. It is assumed that the helicopter is in good operating condition and the engine is developing its rated power. The pilot is assumed to be following normal operating procedures and to have average flying abilities. Average means a pilot capable of doing each of the required tasks correctly and at the appropriate times.

Using these assumptions, the manufacturer develops performance data for the helicopter based on actual flight tests. However, they do not test the helicopter under each and every condition shown on a performance chart. Instead, they evaluate specific data and mathematically derive the remaining data.

Autorotational Performance

Most autorotational performance charts state that autorotational descent performance is a function of airspeed and is essentially unaffected by density altitude and gross weight. Keep in mind that, at some point, the potential energy expended during the autorotation is converted into kinetic energy for the flare and touchdown phase of the maneuver. It is at that point that increased density altitudes and heavier gross weights have a great impact on the successful completion of the autorotation. The rotor disk must be able to overcome the downward momentum of the helicopter and provide enough lift to cushion the landing. With increased density altitudes and gross weights, the lift potential is reduced and a higher collective pitch angle (angle of incidence) is required. The aerodynamics of autorotation has been presented in detail in Chapter 3, Aerodynamics of Flight.

Hovering Performance

Helicopter performance revolves around whether or not the helicopter can be hovered. More power is required during the hover than in any other flight regime. Obstructions aside, if a hover can be maintained, a takeoff can be made, especially with the additional benefit of translational lift. Hover charts are provided for in ground effect (IGE) hover and out of ground effect (OGE) hover under various conditions of gross weight, altitude, temperature, and power. The IGE hover ceiling is usually higher than the OGE hover ceiling because of the added lift benefit produced by ground effect. See Chapter 3, Aerodynamics of Flight, for more details on IGE and OGE hover. A pilot should always plan an OGE hover when landing in an area that is uncertain or unverified.

As density altitude increases, more power is required to hover. At some point, the power required is equal to the power available. This establishes the hovering ceiling under the existing conditions. Any adjustment to the gross weight by varying fuel, payload, or both, affects the hovering ceiling. The heavier the gross weight, the lower the hovering ceiling. As gross weight is decreased, the hover ceiling increases.

Sample Hover Problem 1

You are to fly a photographer to a remote location to take pictures of the local wildlife. Using *Figure 7-1*, can you safely hover in ground effect at your departure point with the following conditions?

   A. Pressure Altitude................................8,000 feet

   B. Temperature...+15 °C

   C. Takeoff Gross Weight.........................1,250 lb

        RPM...104 percent

First enter the chart at 8,000 feet pressure altitude (point A), then move right until reaching a point midway between the +10 °C and +20 °C lines (point B). From that point, proceed down to find the maximum gross weight where a 2 foot hover can be achieved. In this case, it is approximately 1,280 pounds (point C).

Since the gross weight of your helicopter is less than this, you can safely hover with these conditions.
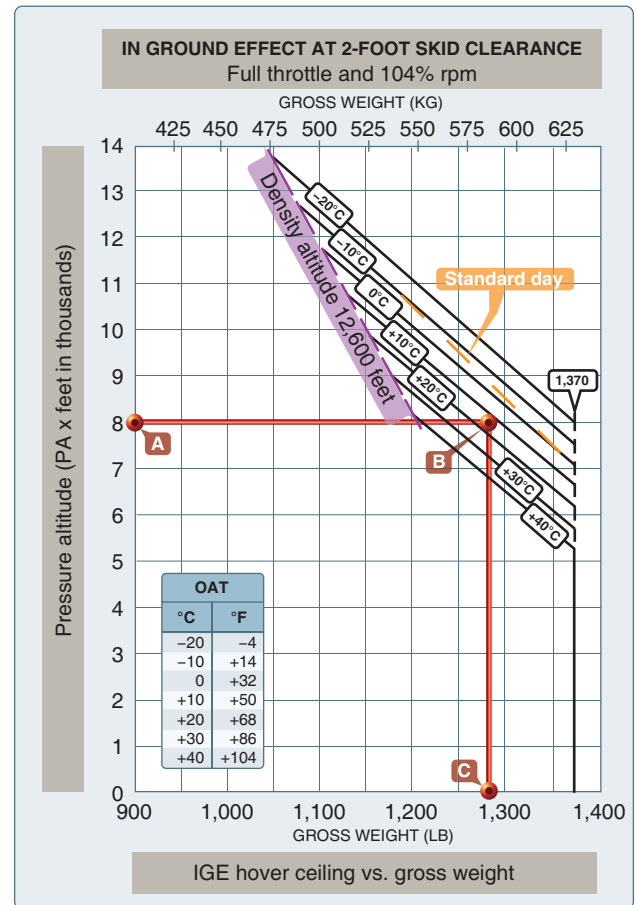

Figure 7-1. *In ground effect hovering ceiling versus gross weight chart.*

Sample Hover Problem 2

Once you reach the remote location in the previous problem, you will need to hover OGE for some of the pictures. The pressure altitude at the remote site is 9,000 feet, and you will use 50 pounds of fuel getting there. (The new gross weight is now 1,200 pounds.) The temperature will remain at +15 °C. Using *Figure 7-2*, can you accomplish the mission?
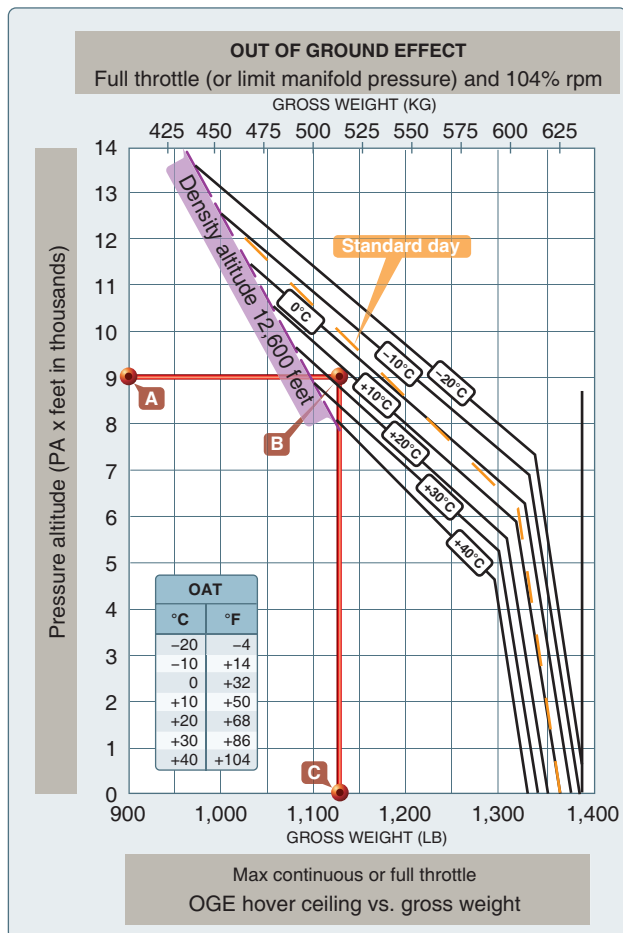

Figure 7-2. *Out of ground effect hover ceiling versus gross weight chart.*

Enter the chart at 9,000 feet (point A) and proceed to point B (+15 °C). From there, determine that the maximum gross weight to hover OGE is approximately 1,130 pounds (point C). Since your gross weight is higher than this value, you will not be able to hover in these conditions. To accomplish the mission, you will need to remove approximately 70 pounds before you begin the flight.

These two sample problems emphasize the importance of determining the gross weight and hover ceiling throughout the entire flight operation. Being able to hover at the takeoff location with a specific gross weight does not ensure the same performance at the landing point. If the destination point is at a higher density altitude because of higher elevation, temperature, and/or relative humidity, more power is required to hover there. You should be able to predict whether hovering power will be available at the destination by knowing the temperature and wind conditions, using the performance charts in the helicopter flight manual, and making certain power checks during hover and in flight prior to commencing the approach and landing.

For helicopters with dual engines, performance charts provide torque amounts for both engines.

Sample Hover Problem 3

Using *Figure 7-3*, determine what torque is required to hover. Use the following conditions:

A. Pressure Altitude . . . . .9,500 feet

B. Outside Air Temperature . . . . 0 °C

C. Gross Weight. . . . . 4,250 lb

D. Desired Skid Height . . . . 5 feet

First, enter the chart at 9,500 feet pressure altitude, then move right to outside air temperature, 0 °C. From that point, move down to 4,250 pounds gross weight and then move left to 5 foot skid height. Drop down to read 66 percent torque required to hover.

Climb Performance

Most of the factors affecting hover and takeoff performance also affect climb performance. In addition, turbulent air, pilot techniques, and overall condition of the helicopter can cause climb performance to vary.

A helicopter flown at the best rate-of-climb speed (V_Y) obtains the greatest gain in altitude over a given period of time. This speed is normally used during the climb after all obstacles have been cleared and is usually maintained until reaching cruise altitude. Rate of climb must not be confused with angle of climb. Angle of climb is a function of altitude gained over a given distance. The V_Y results in the highest climb rate, but not the steepest climb angle, and may not be sufficient to clear obstructions. The best angle of climb speed (V_X) depends upon the power available. If there is a surplus of power available, the helicopter can climb vertically, so V_X is zero.

Wind direction and speed have an effect on climb performance, but it is often misunderstood. Airspeed is the speed at which the helicopter is moving through the atmosphere and is unaffected by wind. Atmospheric wind affects only the groundspeed, or speed at which the helicopter is moving over the Earth's surface. Thus, the only climb performance affected by atmospheric wind is the angle of climb and not the rate of climb.
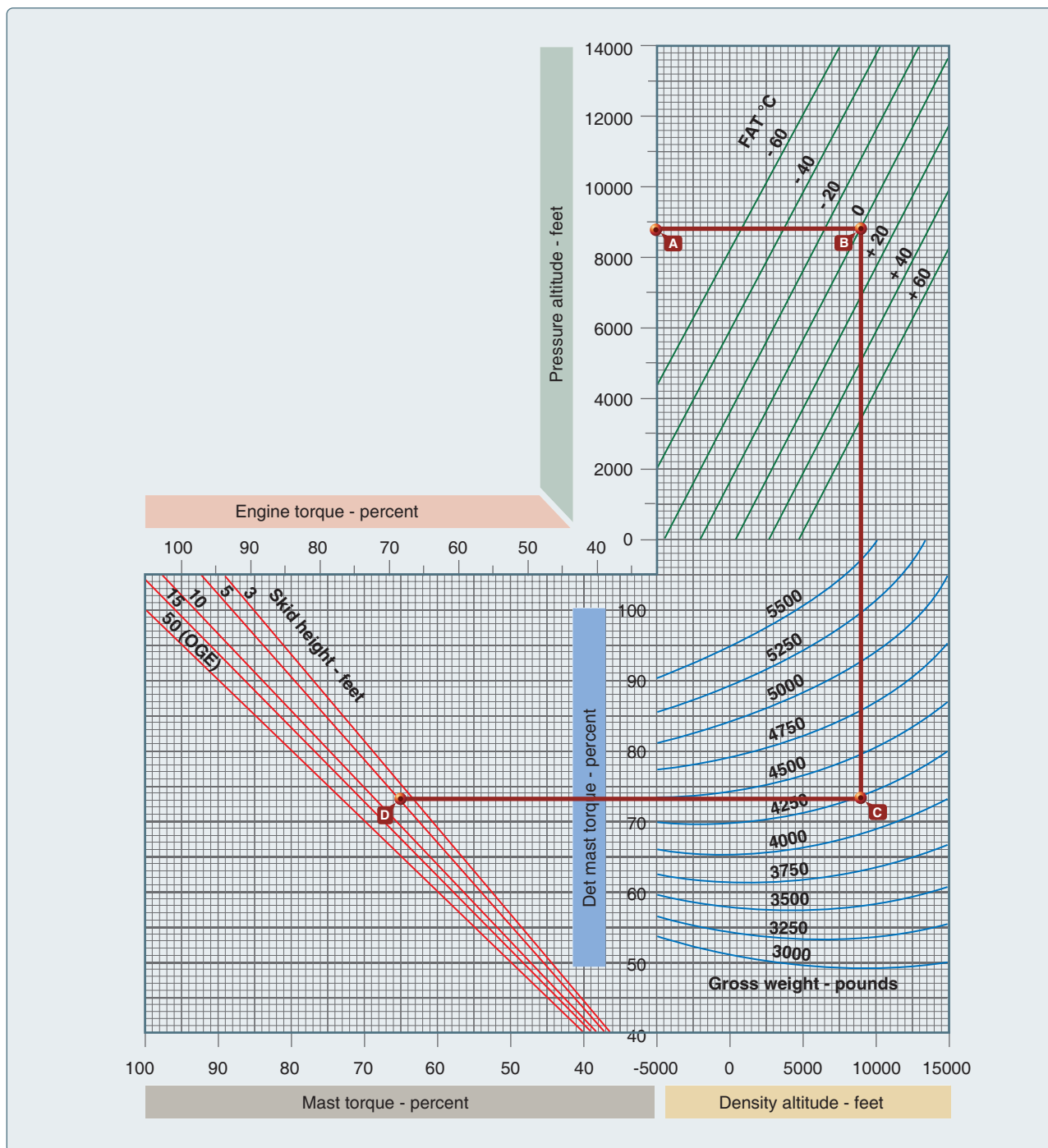
Figure 7-3. *Torque required for cruise or level flight.*

When planning for climb performance, it is first important to plan for torque settings at level flight. Climb performance charts show the change in torque, above or below torque, required for level flight under the same gross weight and atmospheric conditions to obtain a given rate of climb or descent.

Sample Cruise or Level Flight Problem

Determine torque setting for cruise or level flight using *Figure 7-4.* Use the following conditions:

Pressure Altitude... 8,000 feet

Outside Air Temperature....................................... +15 °C

A. Indicated Airspeed..80 knots

B. Maximum Gross Weight................................5,000 lb

With this chart, first confirm that it is for a pressure altitude of 8,000 feet with an OAT of 15°. Begin on the left side at 80 knots indicated airspeed (point A) and move right to maximum gross weight of 5,000 lb (point B). From that point, proceed down to the torque reading for level flight, which is 74 percent torque (point C). This torque setting is used in the next problem to add or subtract cruise/descent torque percentage from cruise flight.
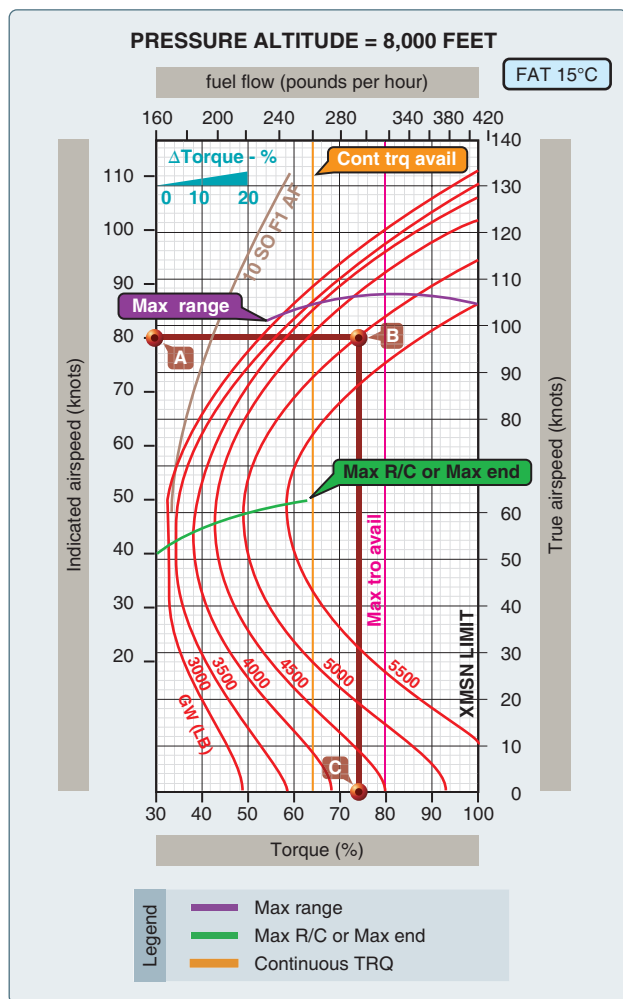

Figure 7-4. *Maximum rate-of-climb chart.*

Sample Climb Problem

Determine climb/descent torque percentage using *Figure 7-5.* Use the following conditions:

A. Rate of Climb or Descent............... 500 fpm

B. Maximum Gross Weight .... 5,000 lb

With this chart, first locate a 500 fpm rate of climb or descent (point A), and then move to the right to a maximum gross weight of 5,000 lb (point B). From that point, proceed down to the torque percentage, which is 15 percent torque (point C). For climb or descent, 15 percent torque should be added/subtracted from the 74 percent torque needed for level flight. For example, if the numbers were to be used for a climb torque, the pilot would adjust torque settings to 89 percent for optimal climb performance.
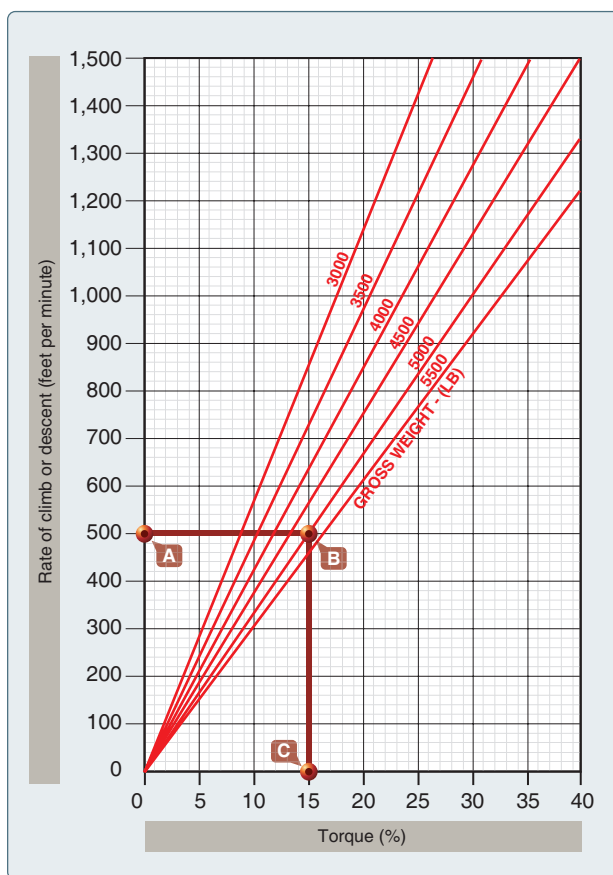

Figure 7-5. *Climb/descent torque percentage chart.*

Chapter Summary

This chapter discussed the factors affecting performance: density altitude, weight, and wind. Five sample problems were also given with performance charts to calculate different flight conditions and determine the performance of the helicopter.